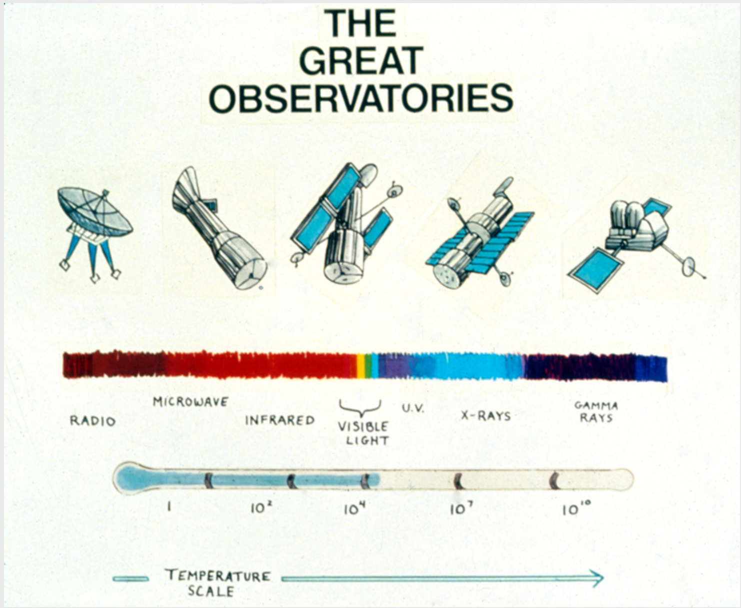
Spitzer Space Telescope

"Though she be but little, she is fierce" – Spitzer's Scientific Success



Michael Werner

Jet Propulsion Laboratory, California Institute of Technology

January 6, 2019

Based in part on research carried out the Jet Propulsion Laboratory, California Institute of Technology, under a contract with NASA

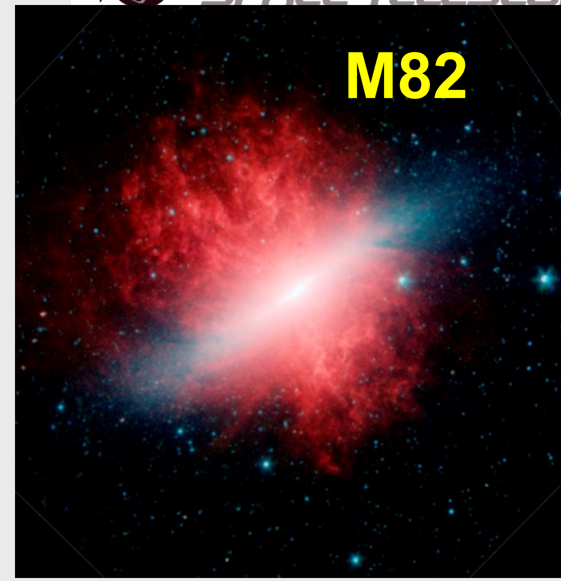
Spitzer Space Telescope

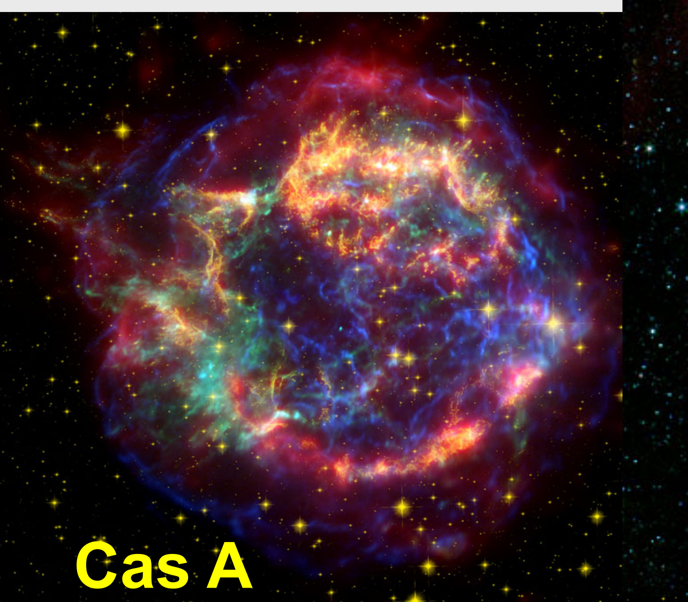
Spitzer thermal test
Lockheed Sunnyvale,
2003

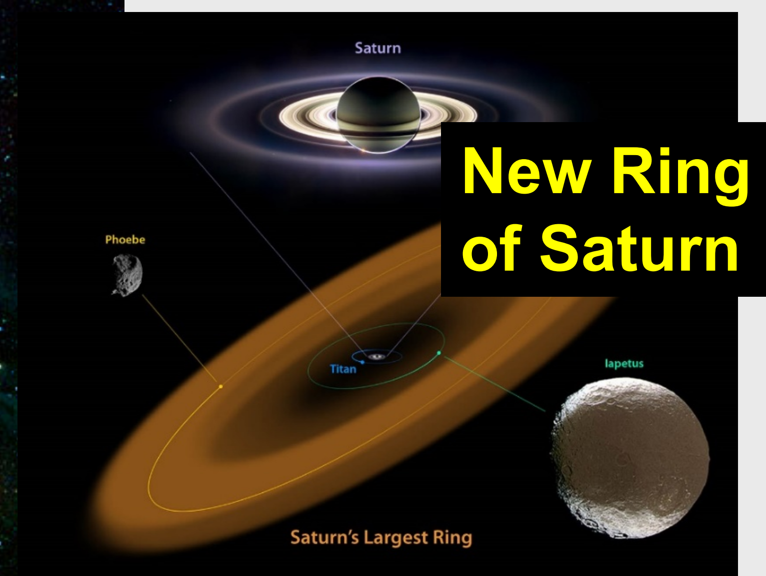
Spitzer's Features

- 85 cm, He- and radiatively cooled telescope
- *Warm launch, August 2003 into heliocentric orbit*
- Imaging/Photometry in seven bands, 3.6-160 μm; spectrophotometry, 5-38 μm and 60-100 μm
- *Arrays up to 256^2 pixels, 5 arc min fields of view*
- Since mid-2009, only 3.6 and 4.5 μm channels available
- *Observing efficiency > 85%*
- Scientific and technical precursor to JWST

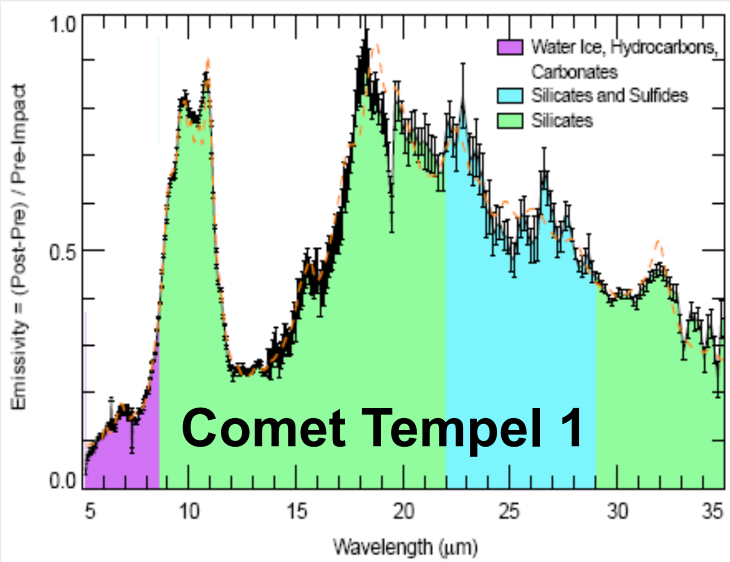
Spitzer Images



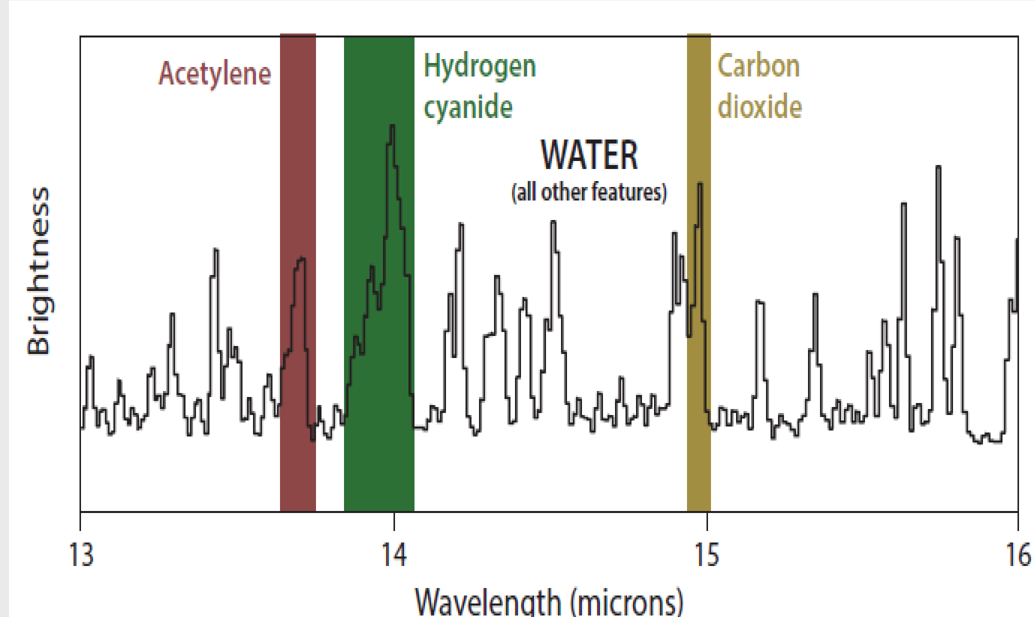




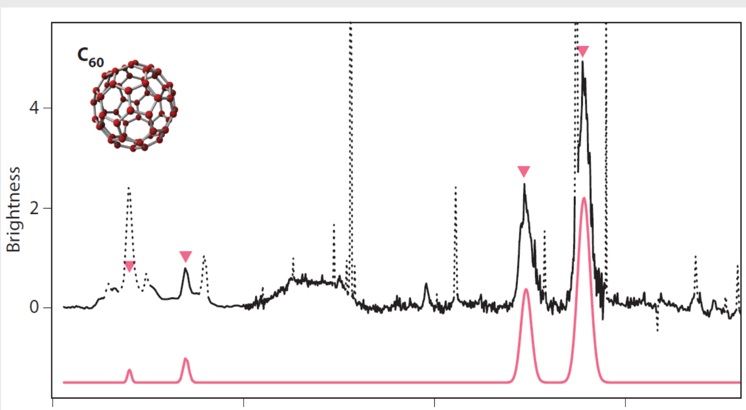
Spitzer Spectra



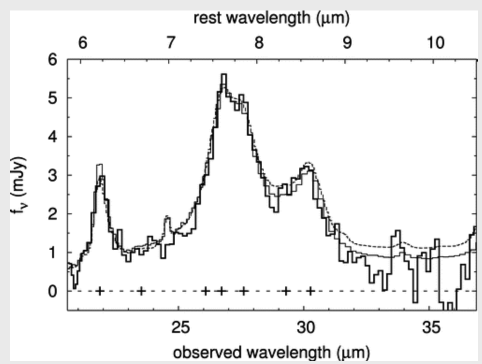
Comet Tempel 1



Organic molecules in planet-forming disk



C_{60} "buckyballs" in the cosmos



Aromatic Hydrocarbons at z~2.5

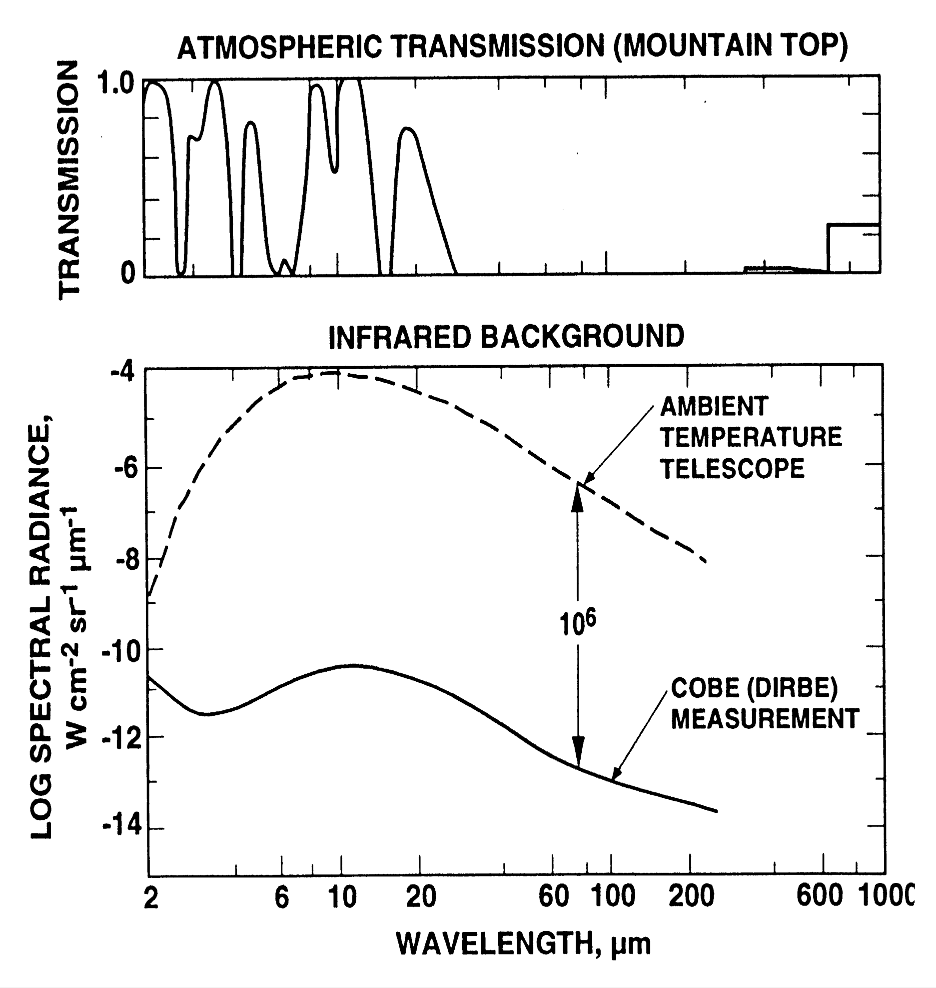
Reasons for Spitzer's Success

- **Technical**
  - *Sensitivity of cryogenic space telescope*
  - *Power of arrays*
  - *Long life*
- **Design choices**
  - *Warm launch into solar orbit*
  - *Limited number of defining science themes*
  - *Simple, robust instruments – limited number of observing modes*
  - *Efficient operations [e.g. campaign scheduling, Legacy science progams]*
- **Scientific considerations**
  - *Successful precursor missions – IRAS and ISO*
  - *Powerful survey capabilities*
  - *Cooperation of Universe [bright young galaxies, exoplanets]*
  - *Contemporaneous with other powerful observatories*
  - *Excellent relations/interactions with the user community*

Most important, it's the people!

The Advantages of Space

- 100% Transmission
- 10^6 Decrease in Sky Brightness
- Gain in sensitivity is 10^3 over ground-based platforms
- A stable environment – Measurements to parts in 10^{-5} or better

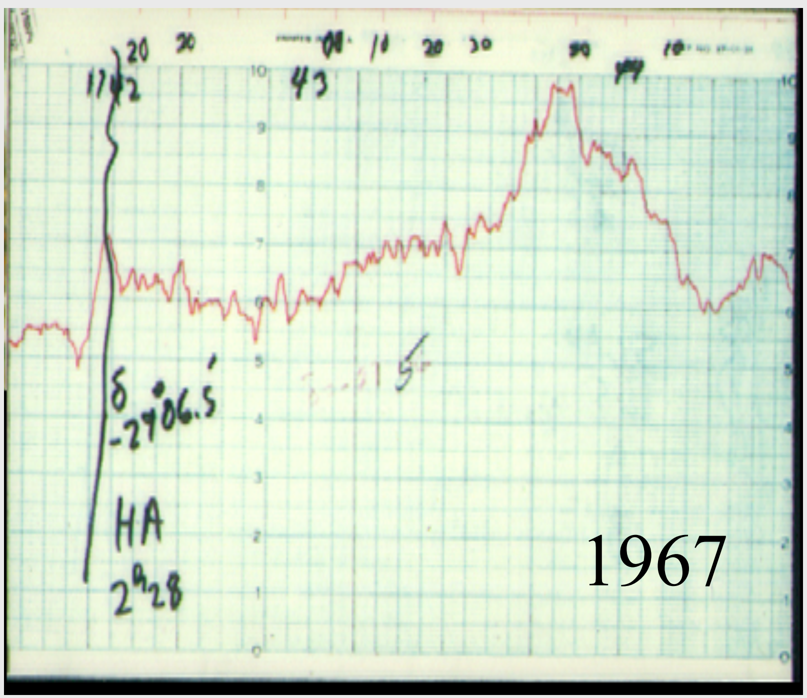


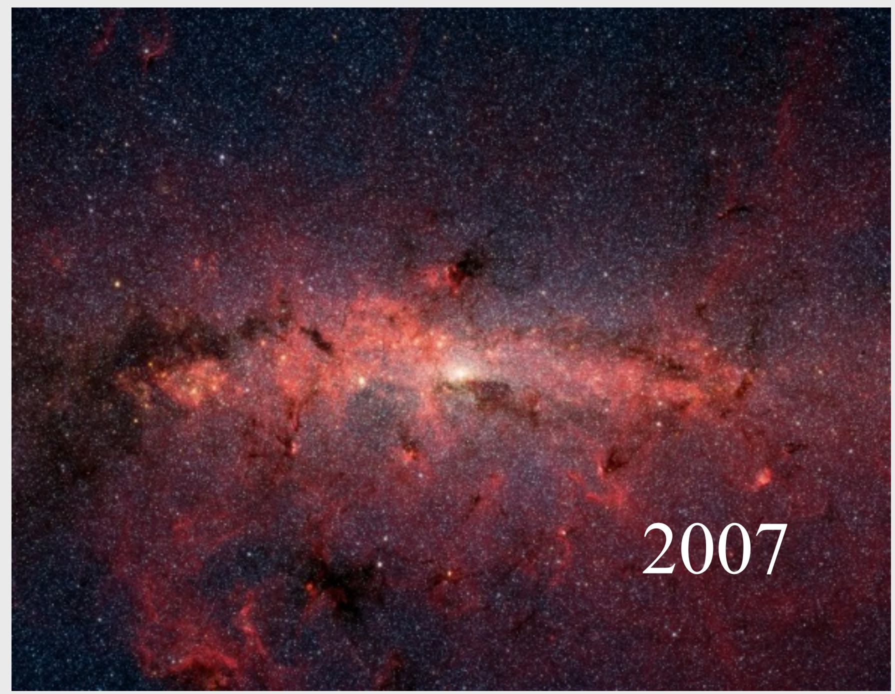
Infrared Images, Then and Now

Galactic Center Images

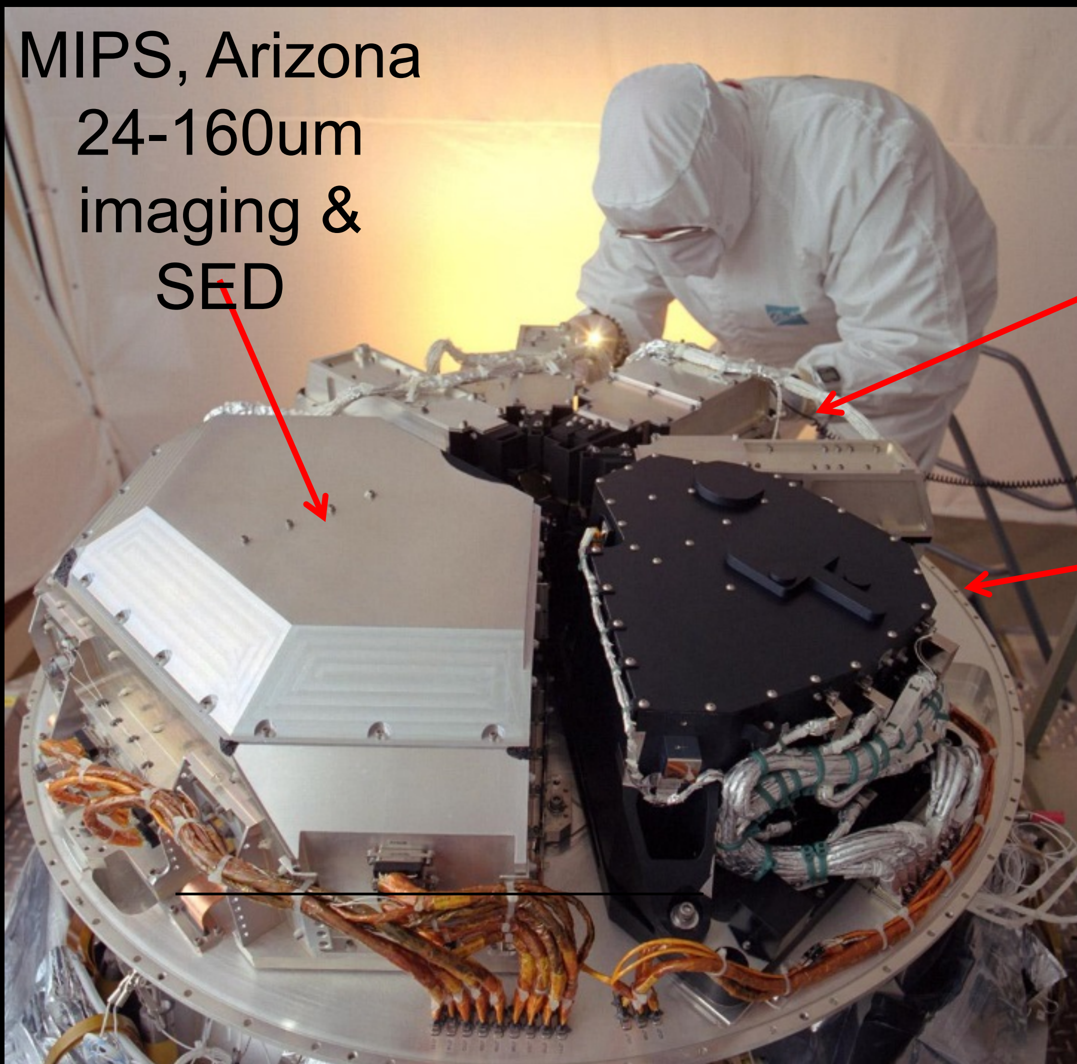
Left – Becklin and Neugebauer
Mt. Wilson 24-inch, 2.2um

Right – Stolovy et al
Spitzer 3.5-to-8um





Spitzer Instruments: Simple and Robust



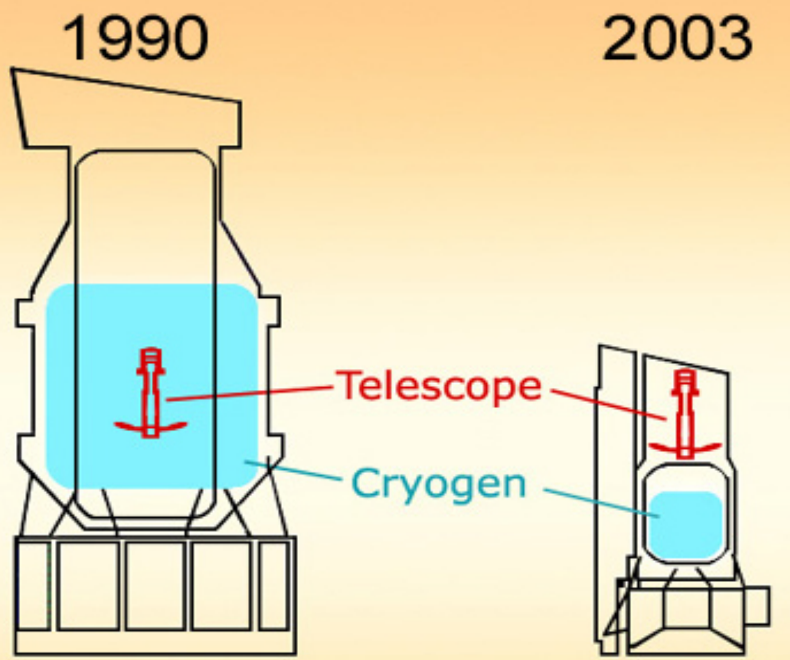
IRS, Cornell
5-40um
spectra

IRAC,
SAO
3.6-8um
imaging

Other Team Members:
Lockheed, Ball, JPL,
GSFC, Caltech

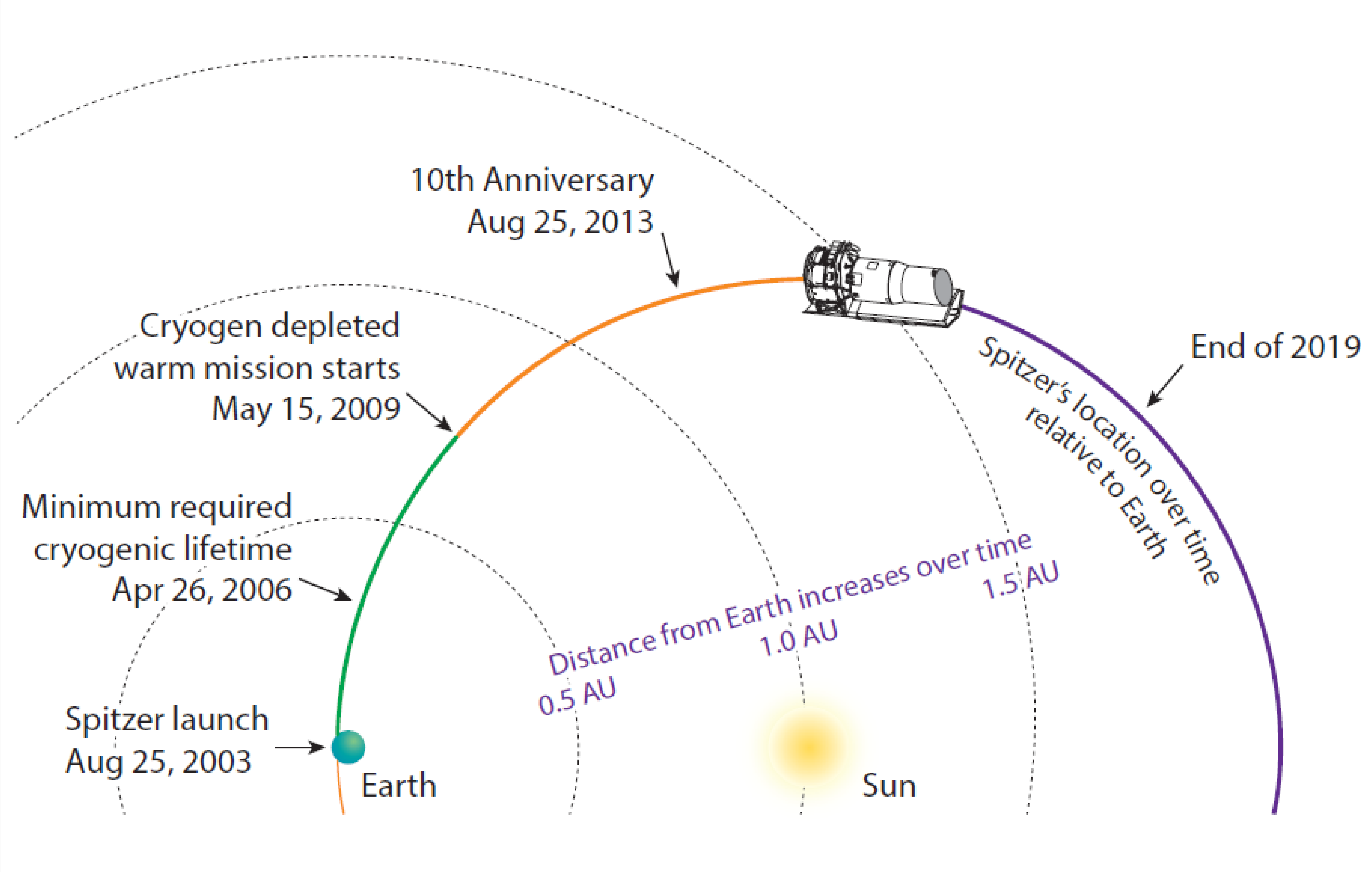
Warm Launch – A Major Innovation

DESIGN CHANGES

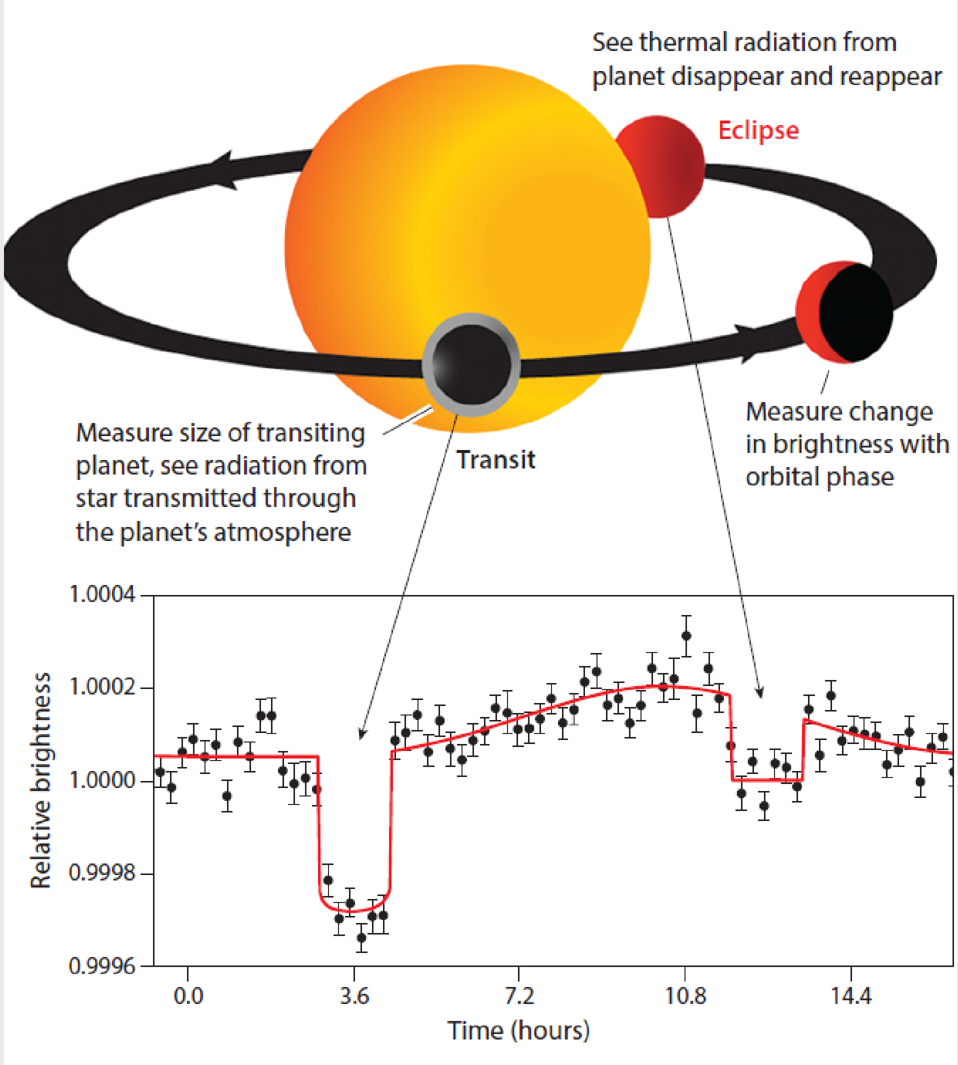


	COLD LAUNCH	WARM LAUNCH
Launch Mass	5700 kg	870 kg
Lifetime	5 years	5 years
Development Cost	~$2.2B	$0.67B
Launch Vehicle	Titan IV	Delta

Solar Orbit Plays Well with Warm Launch



Spitzer Studies Transiting Exoplanets



Transiting exoplanets are ideal targets for study by Spitzer

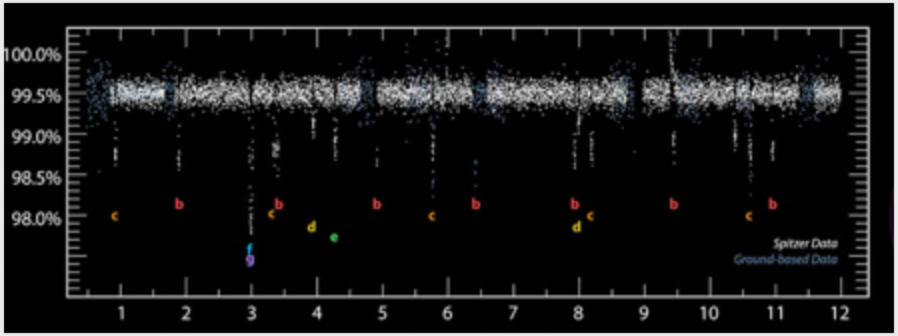
Combined with radial velocity measurements, can fully characterize an exoplanet system

Spitzer Science Center, working with Spitzer users, has driven achievable sensitivity below 50 ppm for bright targets

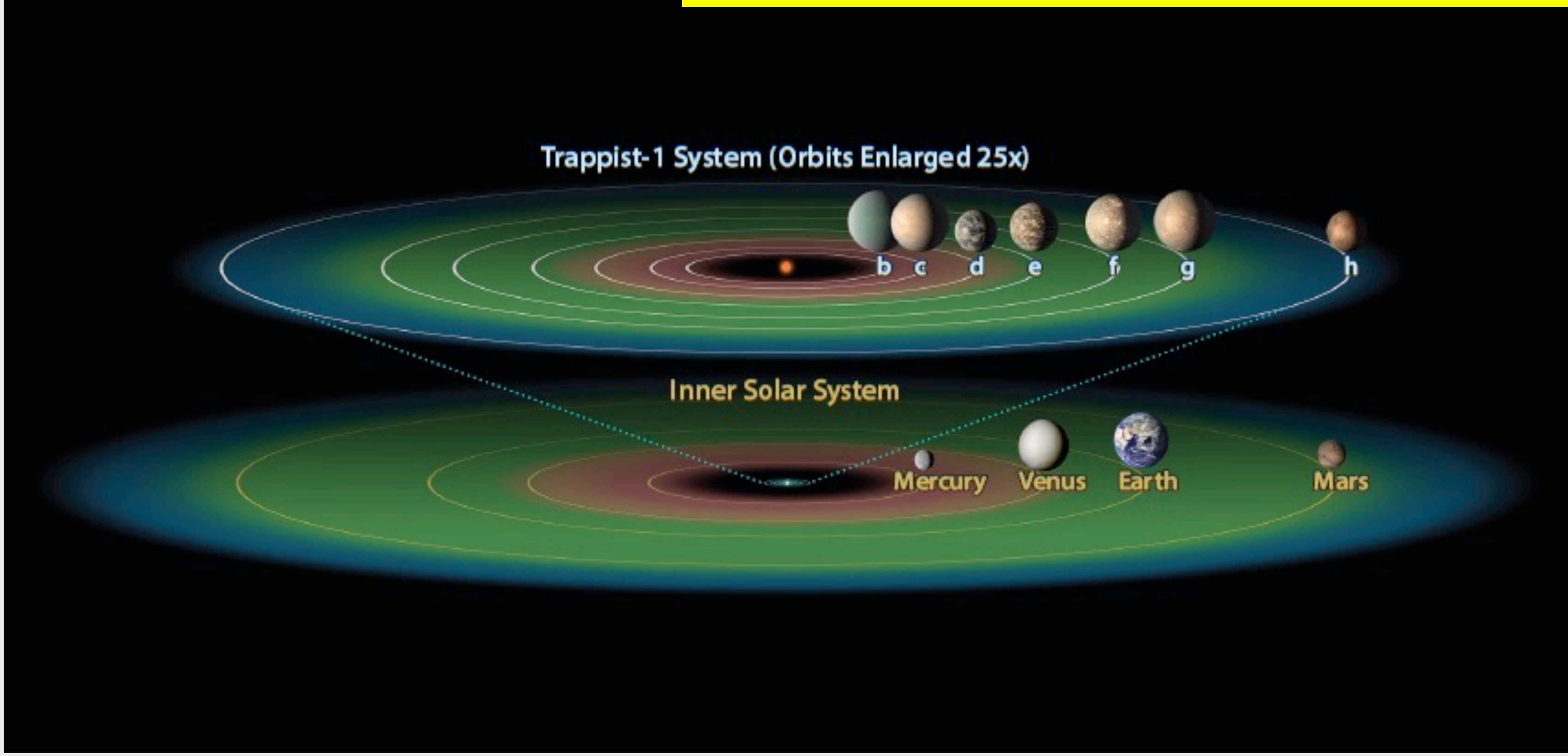
JPL

TRAPPIST-1

SPITZER SPACE TELESCOPE



25 consecutive hours of monitoring of star TRAPPIST-1 by Spitzer identified 7 Earth-sized planets within a fraction of an au of the central M8 star.



TRAPPIST-1 – Family Portrait

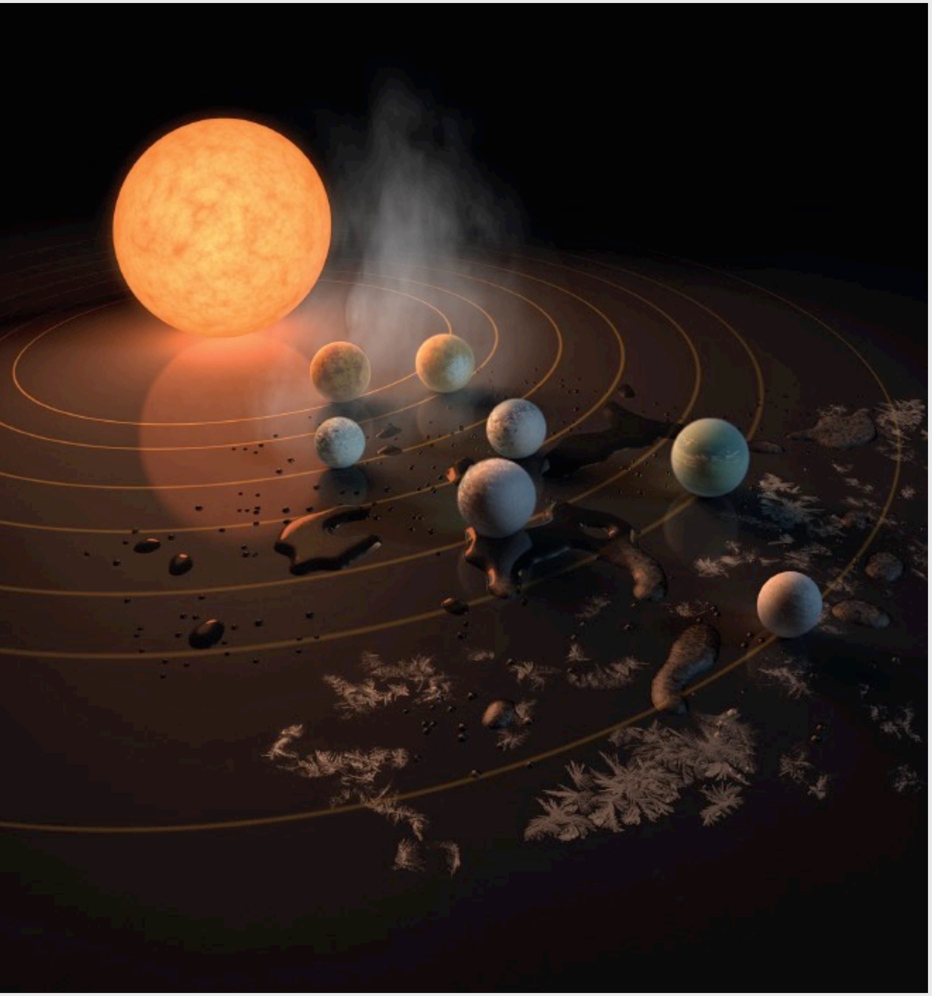


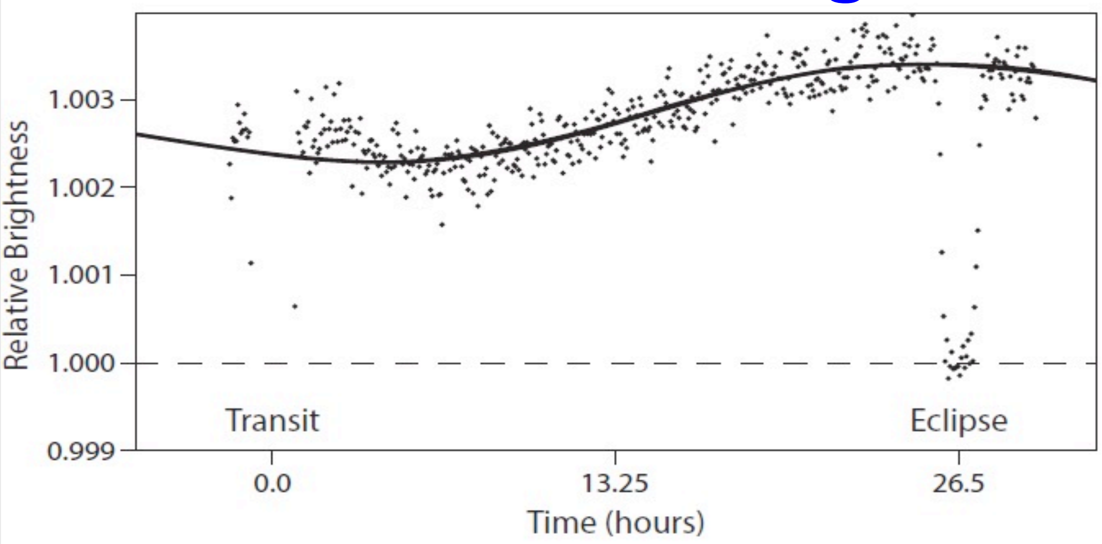
Image by Robert Hurt, IPAC

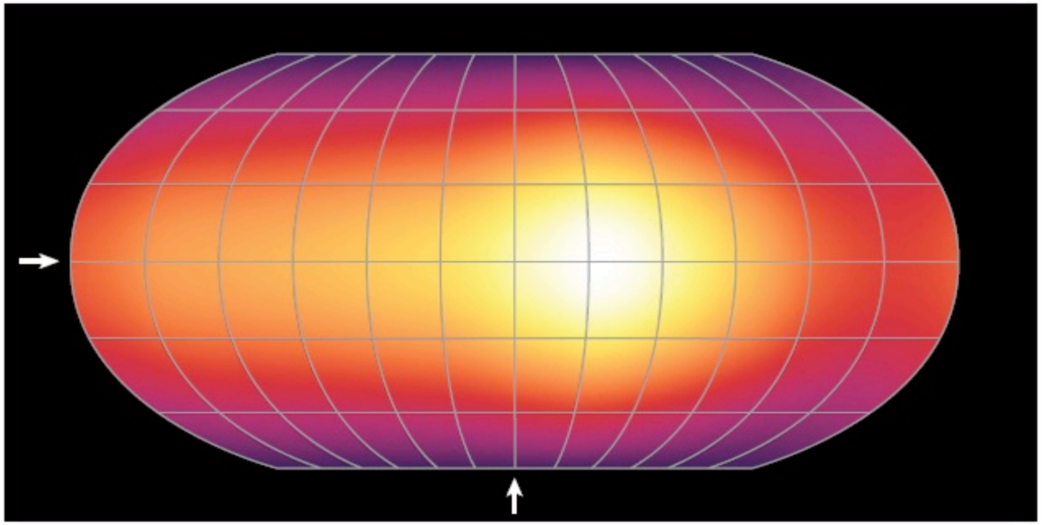
Only three of the seven planets lie in the “habitable zone”, but Michel Gillon et al figure that all seven might host liquid water.

Their team is looking for more systems of this type around late M stars, using the new “Speculoos” telescopes

This startling discovery – and other Spitzer work on exoplanets - facilitated by Spitzer’s orbit, stability, and infrared sensitivity

Exoplanets: Atmospheric Energetics





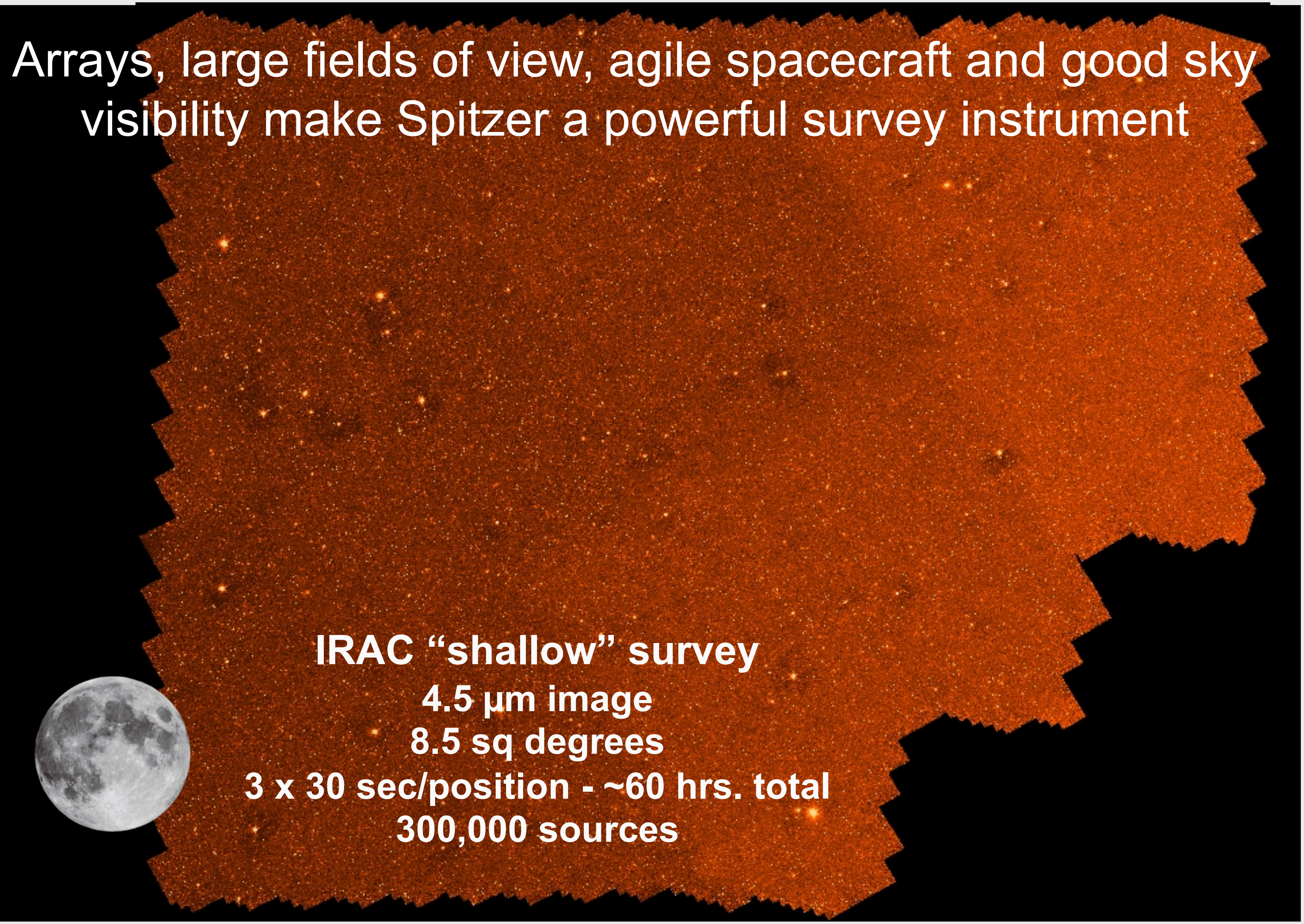
Heather Knutson et al converted Spitzer 8um phase curve of exoplanet HD 189733b into map of temperature on surface of planet.

Hottest point is not the substellar point – high velocity winds redistribute heat on planet's surface

Phase curves facilitated by Spitzer's sensitivity, stability, and ability to carry out long observations

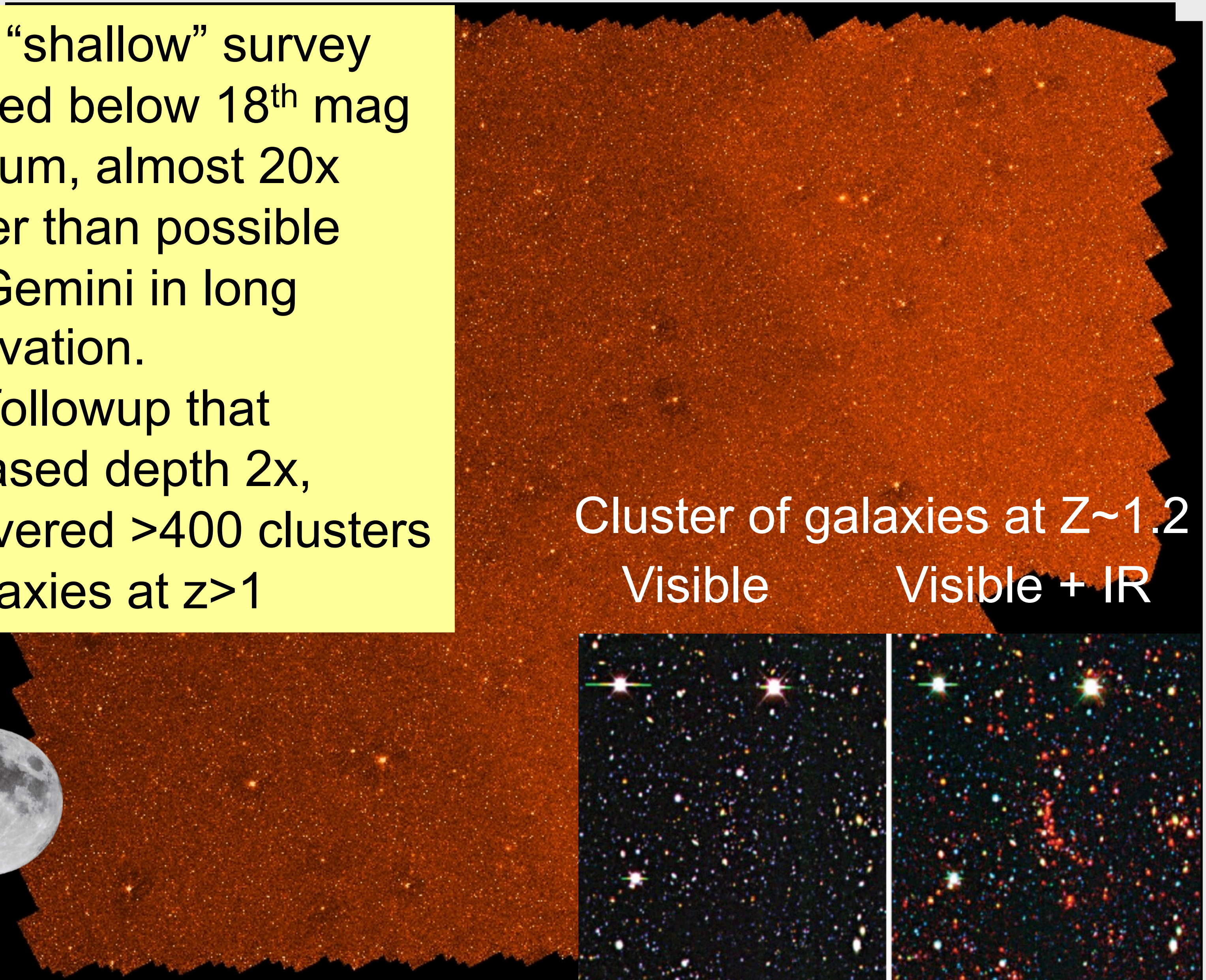
Spitzer Surveys (I)

Arrays, large fields of view, agile spacecraft and good sky visibility make Spitzer a powerful survey instrument



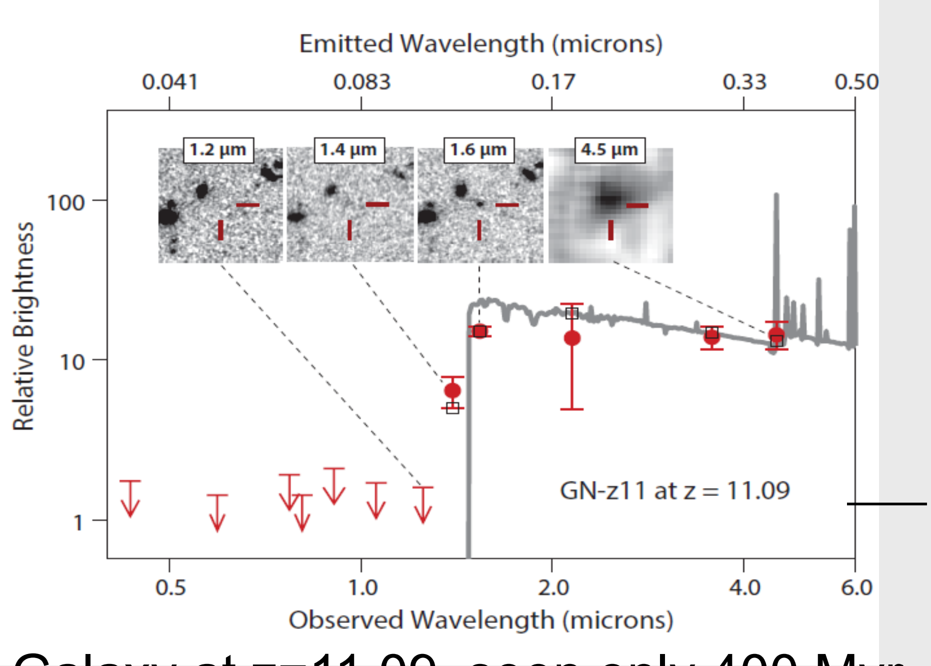
Spitzer Surveys (II)

IRAC "shallow" survey reached below 18th mag at 4.5um, almost 20x deeper than possible with Gemini in long observation.
With followup that increased depth 2x, discovered >400 clusters of galaxies at z>1

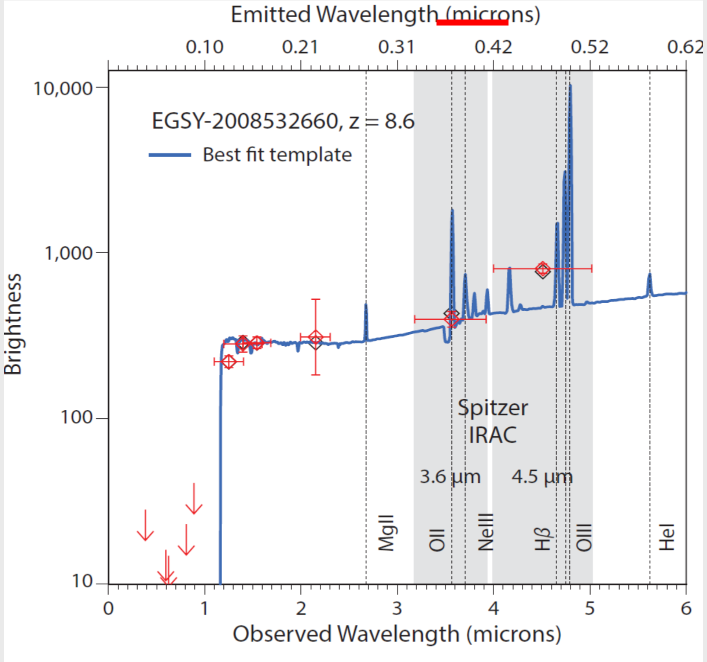


Spitzer Surveys (III)

Spitzer's Deep Surveys, in tandem with HST, probe the Universe to unprecedentd depths, setting stage for JWST



Galaxy at z=11.09, seen only 400 Myr after the Big Bang, has stellar mass $\sim 10^9 M_{sun}$ and luminosity $\sim 10^{11} L_{sun}$. Galaxies this big were not expected at this early epoch.



Spitzer "color" for z~8.5 galaxies like this select best candidates for follow on spectroscopy from ground and JWST.

What's Next for Spitzer?

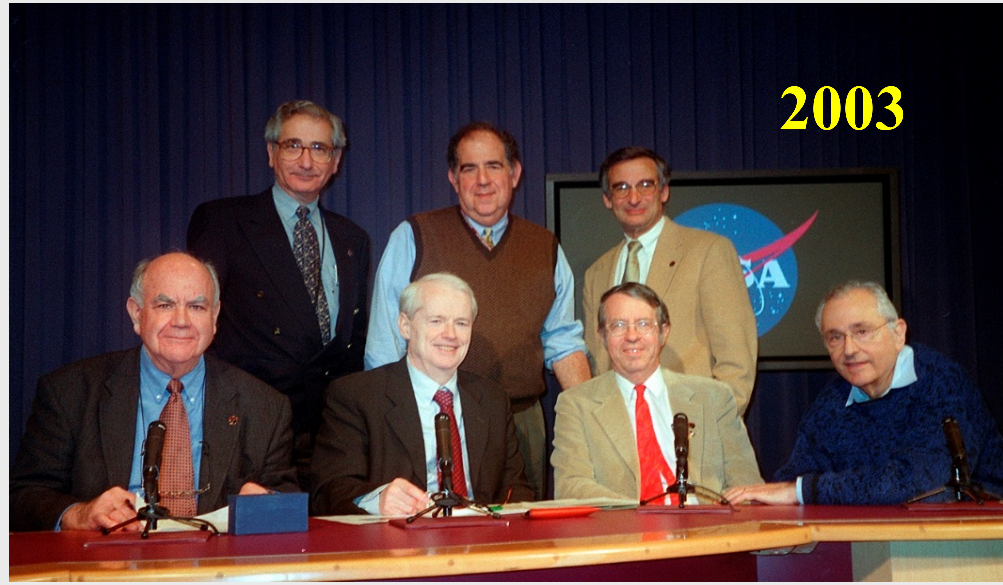
- Currently funded to operate through end of Jan 2020
  - Limitation is $, not physics or engineering
- We plan three additional proposal deadlines
  - First deadline is Feb 8. See Spitzer Science Center for details.
  - Expect great proposal pressure: TESS, JWST preps, etc.
  - 3000 additional hours will be awarded
- In subsequent years, Spitzer data will be available through the IRSA archive at IPAC, with support available through ROSES call

Conclusion

- The scientific legacy of Spitzer will live on for decades

For further information, see Werner and Eisenhardt [*More Things in the Heavens*…Princeton, June 2019]

Final Thought: It's the People



- The success of Spitzer can be most directly traced to the people who brought it to life, and to those who have used it so effectively
- *The Spitzer Science Working Group provided invaluable scientific, technical, and political support and continuity throughout this journey*
- I particularly acknowledge Frank Low, Jim Houck, and Mike Jura [and John Bahcall], who lived to see the success of Spitzer but, regrettably, are with us no longer